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Original Article

EXPERIMENTAL INVESTIGATION OF MAJOR AND MINOR STRAINS IN DIFFERENT REGIONS OF DEEP DRAWN CUPS

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ABSTRACT

Drawing is one of the most important processes for forming sheet metal parts. It is used to manufacture parts in industries such as automobile, aerospace and home appliance, etc. The parts produced include cooking pans, kitchen sinks, automobile panels, gas tanks, fountain pen caps, etc. A deep drawn cup has different regions like, flange, corner radius, side walls and flat bottom. The values of stresses and strains vary throughout the cup (i.e in different regions). The objective of the present work is to perform an experimental investigation of major and minor strains in the different regions of deep drawn cups. In this work, the cups are drawn with different blank thickness and major strain and minor strain are measured in different regions of the cup. Also a comparison is made by drawing graphs between major strain(y axis) and minor strain (x axis) for cups drawn with different sheet thickness. By performing this study it will be possible to find out which region of the cup is strained maximum, hence where exactly fracture is likely to occur. Also, areas which are not stressed can be identified and in those areas, heat treatment is not necessary. It will also be possible to know which sheet thickness can take a maximum and minimum amount of stresses and strains. The material selected for this work is Brass. The diameter and heights of cups drawn are 200mm and 40mm respectively. The sheet thickness selected is 0.71, 0.8and 0.88mm. This work was carried out at Metal industries, Sanathnagar, New modern stone company, Hyderabad and metal forming lab of CBIT. The studies revealed that the die corner radius, region (neck) of the cup has maximum strain. Hence this region is the source for a fracture to take place.

***KEYWORDS:** Deep drawing, Blank thickness, Blanking, Electrochemical etching, Major strain & Minor strain*

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INTRODUCTION

Deep drawing is one of the widely used sheet metal forming processes in the industries involved in mass production of cup-shaped components. During this process, a flat blank of sheet metal is shaped by the action of a punch forcing the metal into a die cavity. Deep drawn products, in modern industries usually have a complicated shape, so these have to undergo several successive operations to obtain a final desired shape. This process is used to manufacture complicated parts from sheet metal in many industries such as automobile, aerospace and home appliance. The parts produced include cooking pans, containers, sinks, automobile parts such as panels and gas tanks and so on. Figure 1 shows a schematic diagram of the deep drawing process.

The equipment for deep drawing processes involves a double action press, one for the blank holder and one for the punch. Both mechanical and hydraulic presses are used in manufacturing industry. The shape of a deep-drawn part is not just limited to a circle or square, but more complex contours are possible. However, as the complexity goes up, the manufacturing difficulties increase rapidly

In deep-drawing process, there are several defects which occur like wrinkling, earring, excessive thinning of the cup and rupture of the blank. Figure.2 shows defects in deep drawn cups. These defects usually occur due to unsuitable or non-optimal variables in the deep drawing process. By controlling these parameters ,it is possible to get defect free components. A deep-drawn cup has different regions like, flange, corner radius, side walls and flat bottom. The values of stresses and strains vary throughout the cup (i.e in different regions). The objective of the present work is to perform an experimental investigation of major and minor strains in the different regions of deep drawn cups.

By carrying out this work it will be possible to estimate and predict regions with high strains in deep drawn cups. This would also help in predicting the occurrence of fracture in the drawn cups. Further, in the cups drawn the areas which are not stressed can also be identified and for those regions, heat treatment is not required.

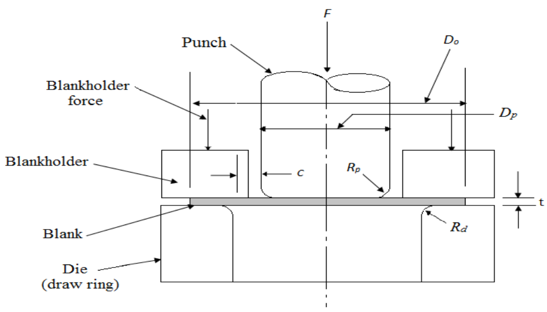


Figure 1: Schematic Diagram of Deep Drawing Process

Figure 2: Defects in Deep Drawn Cups

METHODOLOGY

The methodology involved in carrying out the present work consists of the following steps:

- Cutting raw material from rolled steel at '**Rishab trading company, Balanagar, Hyderabad.**
- Cutting the sheet metal into circular blanks at '**Metal Industries, Sanathnagar, Hyderabad.**
- Electrochemical etching of grid pattern on circular blanks at '**New Modern stone company, Hyderabad.**
- Deep drawing of the circular blank using the hydraulic press in '**Metal industries, Sanathnagar, Hyderabad.**
- Measuring major axis and minor axis in different regions of a drawn cup.
- Determining the % major strain and % minor strain in different regions of the cup.
- Drawing graphs between % major strain and % minor strain with distance from the center of the cup. In this work, three different blank thickness of 0.7, 0.8 and 0.88mm are considered. Cups drawn with this three different thickness are analyzed and compared to find the regions with high strains. The major axis of the ellipse represents

the major direction and magnitude of stretching. The major strain is the engineering strain in this direction, and is always positive, because of sheet-metal stretching. The minor axis of the ellipse represents the magnitude of the stretching or shrinking in the transverse direction of the sheet metal. The material selected for this work is Brass (CuZn40).

Figure 3: Circular Blank Cutting Operation

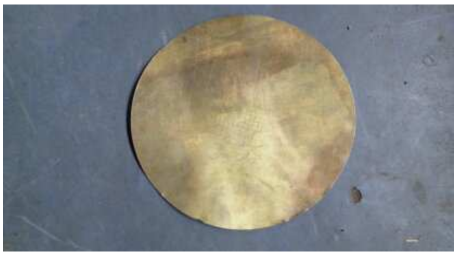


Figure 4: Circular Blanks Made up of Brass

Figure 5: Circular Blanks with Circular Grid Pattern done by Electrochemical Etching

Figure 6: Brass Cups With Elliptical Grid Pattern after Drawing

Figure 7: Deep Drawing Operation in Hydraulic Press

Figure 8: Deep Drawn Cup with Grid Pattern

Figure 3 shows circular blanks being cut at Metal Industries, Sanatnagar. The circular blank made up of brass is seen in Figure 4. Figure 5and Figure 6 show blanks with a circular grid pattern. Figure 7 shows a hydraulic press used for the deep-drawing process. Figure 8 shows deep drawn cup with the elliptical grid pattern. Figure 9 shows different regions of the cup where measurement of major strain and minor strain is carried out. The major and minor strains in different regions of a deep-drawn cup are calculated using the formulas given below:

- $$\text{Major strain} = \frac{\text{Major axis of the ellipse} - \text{Original circle diameter (etched)}}{\text{Original circle diameter (etched)}} \times 100$$
- $$\text{Minor strain} = \frac{\text{Minor axis of the ellipse} - \text{Original circle diameter (etched)}}{\text{Original circle diameter (etched)}} \times 100$$

The VonMises strain or effective strain is calculated using the formula: $\frac{2\sqrt{2}}{3}(\sqrt{\varepsilon_1^2 + \varepsilon_2^2 - \varepsilon_1 \times \varepsilon_2})$

Where, ε_1 and ε_2 are major and minor strains.

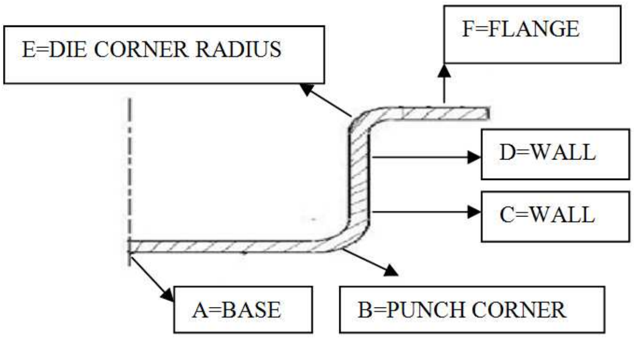


Figure 9: Different Regions of Deep Drawn Cup

RESULTS AND DISCUSSIONS

The table1 shows values of % major strain and % minor strain and VonMises strain obtained in different regions of the drawn cup for sheet thickness 0.71 mm. Similarly, table 2 and table 3 shows the above-mentioned details for sheet thickness 0.8 mm and 0.88 mm.

Table 1: % Major Strain, Minor Strain and VonMises Strain in Different Regions of Cup for Sheet Thickness 0.71mm

Material: Brass **Sheet thickness:** 0.71mm **Blank diameter:** 274.4mm			**Electrochemical Etched Circle Dia=14mm**			**VonMises Strain ($\times 10^{-3}$)**
S. No.	**Distance of Ellipse from Centre of the cup. (mm)**	**Major Diameter of Ellipse (mm)**	**% Major Strain**	**Minor Diameter of Ellipse(mm)**	**% Minor Strain**	
1	A=0	14	0	14	0	0
2	B=80	16.5	17.8	13.3	-5	149.6
3	C=103	18.2	30	10.1	-27.	272.2
4	D=115	19.14	36.7	11.2	-20	299.9
5	E=121	16.2	15.7	10	-28.5	233.04

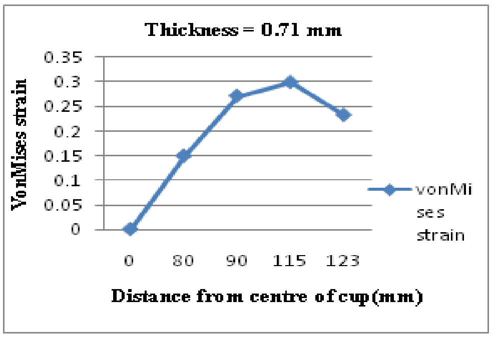
Table 2: % Major strain, Minor Strain and VonMises Strain in Different Regions of Cup for Sheet Thickness 0.8mm

Material: Brass **Sheet thickness:** 0.88mm **Blank diameter:** 330.2mm		**Electrochemical Etched Circle dia: 7mm**				**VonMises Strain ($\times 10^{-3}$)**
S. No.	**Distance of ellipse from centre of the cup. (mm)**	**Major Diameter of Ellipse (mm)**	**% Major Strain**	**Minor Diameter of Ellipse (mm)**	**% Minor Strain**	
1	A=0	7	0	7	0	0
2	B=95	7.5	7	6.7	-4.2	57.5
3	C=102	7.8	11	6.4	-8.5	94.16
4	D=107	8	14.2	6.2	-11.4	121.9
5	E=113	7.2	2.8	6.1	-12.8	78.8

Table 3: % Major Strain, Minor Strain VonMises Strain in Different Regions of Cup for Sheet Thickness 0.88 mm

Material: Brass **Sheet thickness:** 0.8mm **Blank diameter:** 330.2mm			**Electro Chemical Etched Circle dia:** 7mm			**VonMises strain** ($x10^{-3}$)
S. No	**Distance of Ellipse from Centre of the Cup. (mm)**	**Major Diameter of Ellipse (mm)**	**% Major Strain**	**Minor Diameter of Ellipse(mm)**	**% Minor Strain**	
1	A=0	7	0	7	0	0
2	B=80	7.4	5.7	6.86	-2	47.22
3	C=90	7.7	10	6.7	-4.2	81.99
4	D=115	8.04	14.8	6.5	-7.1	120.7
5	E=123	7.2	2.8	6.34	-9.4	78.8

Figure 10 shows variation for VonMises strain in different regions of thecup. Starting from the center of the cup (A) to die corner radius (E) For various thickness. Figure 10 (a) is the graph for sheet thickness 0.7 mm, Figure 10 (b) is the graph for sheet thickness 0.8 mm and Figure 10 (c) is the graph for sheet thickness 0.88 mm. From the above Figure, it is seen that the ratio of % of major strain/minor strain increases and then decreases. It is highest at D (die corner radius, region) and least at A which is the base of the cup. This may be because of the fact that the narrow ring of metal is subjected to necking induced by tensile stress.



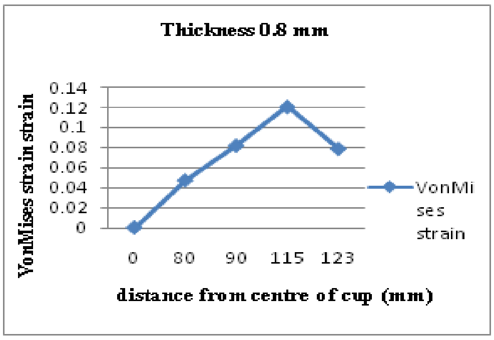


Figure 10: (a) **Figure 10: (b)**

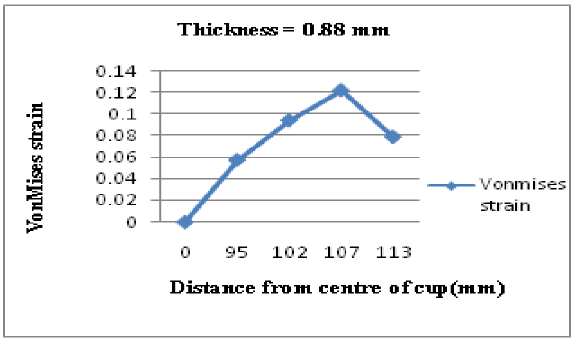


Figure 10: (c)

Figure 10: Variation of VonMises Strain along the Walls of Cup Starting from the Centre of Cup
Figure 10 (a): for Sheet Thickness 0.71 mm
Figure 10 (b): for Sheet Thickness 0.8mm
Figure 10 (c): for Sheet Thickness 0.88 mm

Figure 11 shows a variation of major strain and minor strain with distance along the walls of the cup starting from the center of the cup to die corner radius. It is seen from Figure 11 the % major strain first increases and then decreases and the %minor strain increases continuously from center of the cup to die corner radius region.

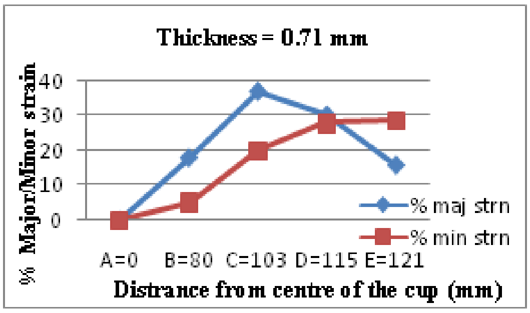


Figure 11: (a)

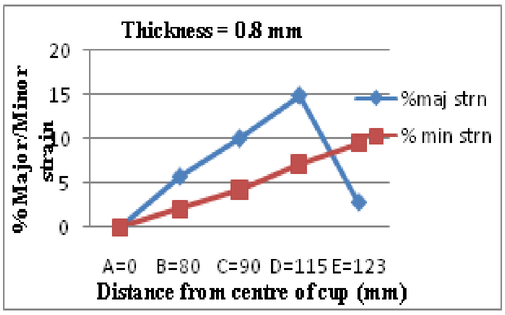


Figure 11: (b)

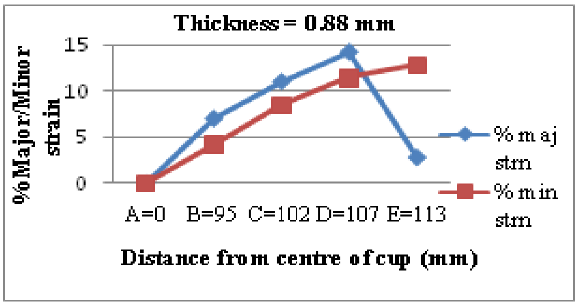


Figure 11: (c)

Figure 11: Variation of Major Strain and Minor Strain with Distance along the Walls of Cup Starting from the Center of Cup
Figure 11 (a): For Sheet Thickness 0.71 mm 11
Figure 11(b): For Sheet Thickness 0.8 mm 11
Figure 11 (c): for Sheet Thickness 0.88 mm

CONCLUSIONS

The conclusions of this work are as given below

- The experimental investigation reveals that the neck region of the cup (i.e., below die corner radius. region 'D') has a maximum value of VonMises strain (i.e effective strain).
- It is also found that with the increase in sheet thickness the maximum value of VonMises strain decreases.
- The maximum value of VonMises strain is found is to be 299.9 x10^{-3} at D for sheet thickness 0.71mm followed by 121.9 x 10^{-3} at D for sheet thickness 0.8mm.
- The minimum value of VonMises strain is found to be at the bottom portion of the cup (base) as there is no deformation in this region.
- The % major strain first increases and then decreases and the %minor strain increases continuously from the center of the cup to die corner radius region.

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